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Environment, Safety, and Health

Volume II

Part 20: Ionizing Radiation/Nonionizing Radiation

Document 20.6
Criticality Safety

Recommended for approval by the ES&H Working Group

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New document or new requirements

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20.6

Criticality Safety*

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* **Editorial revision**

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Criticality

1.0 Introduction

LLNL requires that fissionable materials shall be handled, processed, stored, and transported so that the probability of a criticality accident is acceptably low.

This document describes the LLNL Criticality Safety Program and applies to personnel, activities, equipment, and facilities involving fissionable materials. All personnel who work with or who are responsible for managing activities involving fissionable materials must comply with the requirements in this document.

2.0 Criticality Hazards

Operations with significant quantities of fissionable materials could present the risk of a criticality accident. A criticality accident may expose workers to high, potentially lethal, levels of neutron and gamma radiation and result in a loss of containment, releasing radioactive isotopes into the environment.

3.0 Criticality Safety Controls

Criticality safety is a key element in the Laboratory's Environment, Safety, and Health (ES&H) Program. The principal objective of the Criticality Safety Program is to ensure that the likelihood of an accidental criticality is acceptably low when processing, storing, or transporting fissionable materials. Specific requirements and guidance on criticality safety are provided in the following sections.

3.1 Safety Plans

Activities involving significant quantities of fissionable materials shall be clearly described in an approved safety plan governing both the material involved and the operations (see Sections 3.4, 3.5, and 3.6). The safety plan shall specify all criticality safety controls and the criticality hazard type (see Section 5.2 for details). Criticality safety controls may include

- Fissionable material mass limits.
- Liquid volume limits.

- Moderator and reflector restrictions.
- Geometry controls.
- Physical and chemical form controls.
- The minimum spacing between adjacent workstations (if applicable).
- Use of neutron absorbers (poisons).

The safety plan must be written, reviewed, and approved in accordance with Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual*, and all controls must be in place before the operation can begin. Changes to a safety plan that may affect criticality safety shall be reviewed by the appropriate member of the Criticality Safety Section as part of the ES&H Team review.

3.2 Safety Analyses

The authorization basis and safety analysis planning shall include a criticality safety review if the activities will involve significant quantities of fissionable materials. The ES&H Team shall contact the Criticality Safety Section for this review.

3.3 Criticality Safety Evaluations

Operations in some facilities or workstations may be authorized on the basis of the controls and limits specified in Sections 3.5 and 3.6. Operations that do not meet the criteria specified in these sections will require a criticality safety evaluation specific to the facility or operation. Figure 1 is provided as an aid in determining the requirements for an operation- or facility-specific criticality safety evaluation.

For activities requiring a criticality safety evaluation, the Responsible Individual shall ensure that a criticality safety evaluation is performed and documented in consultation with the ES&H Team and facility management. The criticality safety evaluation shall establish operational controls and limits for incorporation into applicable safety plans. All operations involving significant quantities of fissionable materials shall satisfy the Double Contingency Principle, which states: *Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible*.

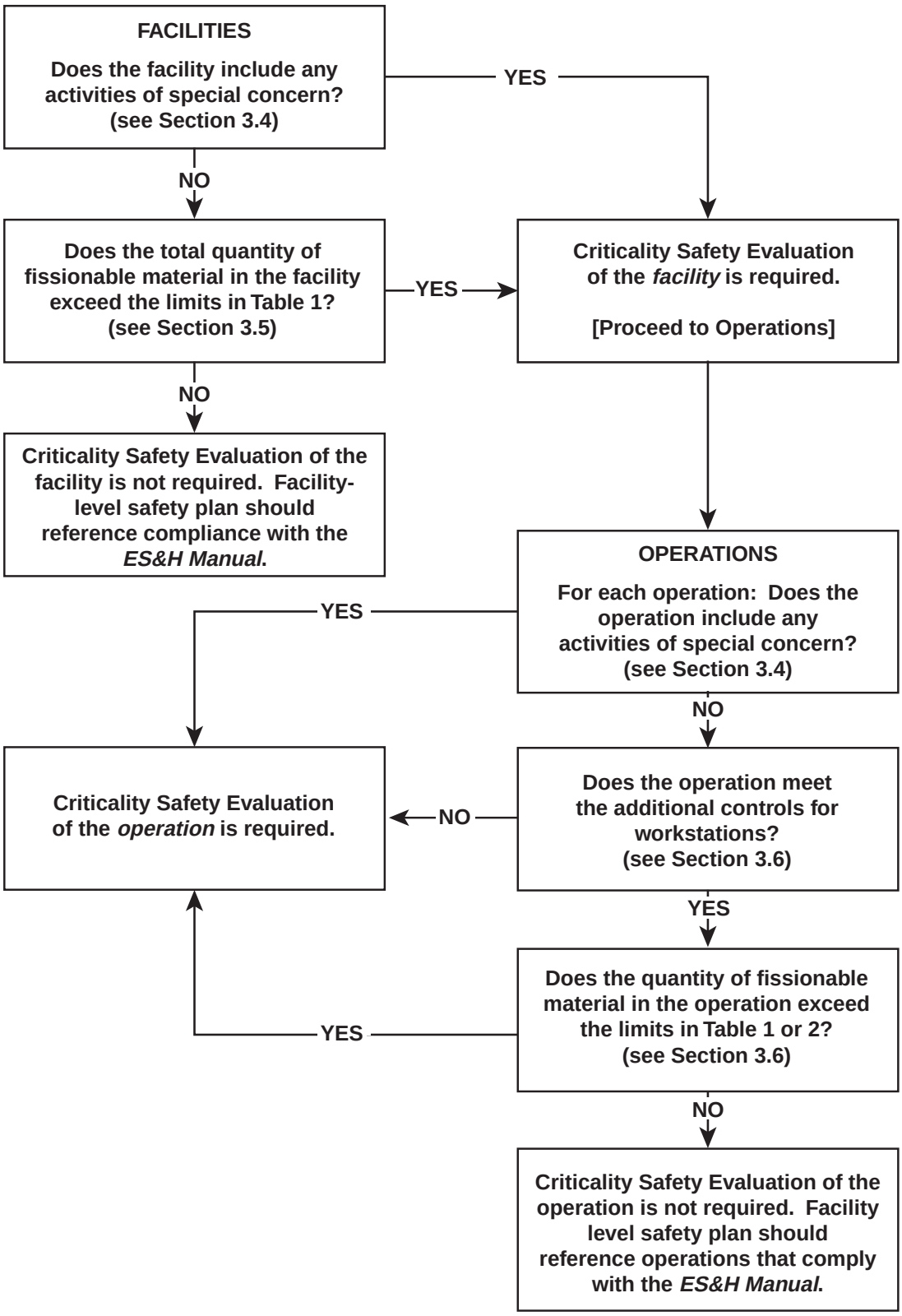

Figure 1. Guidance for determining if a criticality safety evaluation is required for facilities and operations.

3.4 Special Concerns

Certain activities are of special concern to criticality safety because they have the potential for achieving a significantly reduced minimum critical mass. These are activities that include

- Fissionable material in gaseous form.
- Fissionable material at cryogenic temperatures.
- Fissionable material dispersed in a matrix or intimately mixed with hydrogenous materials having a hydrogen density greater than that of water (e.g., polyethylene or oils).
- Fissionable material intimately mixed with or in close proximity to beryllium, graphite, deuterium, or their compounds.

These activities require a criticality safety review on a case-by-case basis. Any questions about whether a specific activity requires a criticality safety review should be referred to the appropriate ES&H Team.

3.5 Criticality Safety Mass Limit Guidelines for Facilities

Any combination of isotopes listed in Table 1 may be permitted in a facility, provided the activities in the facility do *not* constitute a special concern (see Section 3.4) and the combination of isotopes satisfies the following criterion:

$$\sum_{i=1}^{N} \frac{M_i}{L_i} < 1,$$

where

M_i = the total mass inventory of the i^{th} fissionable isotope.

L_i = the mass limit of the i^{th} fissionable isotope.

These mass limits apply to the total inventory of fissionable materials present in the facility, including materials present in sealed sources and in Type A and Type B packaging.

CAUTION

If a facility requires a quantity of an isotope larger than those listed in Table 1 or exceeds the criterion for combinations of isotopes, or if activities within a facility constitute a special concern (discussed in Section 3.4), then the proposed operation will require a safety plan specifying the appropriate criticality safety controls.

Table 1. Fissionable material mass limits for facilities.

Isotope	Mass limit (grams)
$_{99}Es^{254*}$, or any isotope with an atomic number (Z), where ≥99	0.1
$_{98}Cf^{251*}$, or any unspecified isotope with an atomic number, (Z), where $95 \leq Z < 99$	2
$_{95}Am^{242m}$, $_{98}Cf^{249*}$	4
$_{96}Cm^{245*}$	14
$_{86}Rn^{222}$, $_{88}Ra^{223*}$, $_{88}Ra^{224}$, $_{88}Ra^{225*}$, $_{89}Ac^{225}$, or any unspecified isotope with an atomic number (Z), where $88 \leq Z < 95$	15
$_{96}Cm^{243*}$	35
$_{94}Pu^{241*}$	60
$_{99}Es^{253}$	100
$_{94}Pu^{239*}$	145
$_{92}U^{233*}$	195
$_{92}U^{235*}$	290
$_{96}Cm^{247*}$	300
$_{92}U^{232}$, $_{92}U^{234}$, $_{93}Np^{235}$, $_{94}Pu^{236}$, $_{94}Pu^{244}$, $_{96}Cm^{242}$, $_{96}Cm^{246}$, $_{96}Cm^{248}$, $_{97}Bk^{249}$, $_{98}Cf^{250}$, $_{98}Cf^{252}$	500
$_{94}Pu^{238}$, $_{96}Cm^{244}$	1,000
$_{91}Pa^{231}$, $_{95}Am^{243}$, $_{93}Np^{237}$, $_{94}Pu^{240}$, $_{95}Am^{241}$	10,000
$_{94}Pu^{242}$	18,000
Natural or depleted uranium	18×10^6
$_{88}Ra^{226}$, $_{89}Ac^{227}$, $_{90}Th^{228}$, $_{90}Th^{229*}$, $_{90}Th^{230}$, $_{90}Th^{232}$, $_{92}U^{236}$, $_{92}U^{238}$, $_{92}U^{240}$, $_{93}Np^{239}$, or any unspecified isotope with an atomic number (Z) <88	Unlimited

* Fissile isotopes.

The proposed activity also may require

- Additional criticality safety controls (e.g., exclusion of certain reflector materials, moderator controls, and geometry controls).
- Establishment of a workstation (see Section 3.6).

3.6 Criticality Safety Mass Limit Guidelines for Workstations

Fissionable material mass limits for an individual activity or workstation may be based on the mass limits in Table 2, provided that the activity does not constitute a special concern (see Section 3.4) and the following additional controls are implemented:

- The fissionable material is not dispersed in a matrix or is intimately mixed with hydrogenous materials having a hydrogen density greater than that of water (e.g., polyethylene or oils).

- The fissionable material is not intimately mixed with or is in close proximity to beryllium, graphite, deuterium, or their compounds.
- There are no close-fitting reflector shielding or cladding materials.

Table 2. Fissionable material mass limits for workstations.

Isotope	Mass Limit (grams)
$_{94}Pu^{239}$	220
$_{92}U^{233}$	250
$_{92}U^{235}$	350
Any combination of $_{94}Pu^{239}$, $_{92}U^{233}$, or $_{92}U^{235}$	220

Activities with fissionable isotopes not included in Table 2 may be based on the mass limits in Table 1 provided that the activity does not constitute a special concern (see Section 3.4) and the above controls are also implemented.

CAUTION

If the proposed activity requires a quantity of fissionable material larger than those listed in Table 2, or if the controls previously mentioned cannot be satisfied, then the proposed activity requires a safety plan with a specific criticality safety evaluation.

Facilities containing significant quantities of fissionable materials may be divided into a number of workstations for administrative and physical control of the fissionable material. Unless otherwise stated in a safety plan, workstations shall have the following controls:

- The spacing between adjacent workstations shall be sufficient to control neutron interaction between fissionable materials. The recommended minimum spacing is 16 inches edge-to-edge and shall not be less than 12 inches.
- Workstations shall be limited to planar arrangements and shall not be arranged to constitute an effective volume array.

Modifications to a workstation that include changes to the physical geometry or addition of significant quantities of equipment or materials require a criticality safety review. These materials include but are not limited to polyethylene, graphite, concrete, steel, tantalum, tungsten, and beryllium. The ES&H Team shall contact the Criticality Safety Section as early as possible as part of the design/modification process.

Box Loss (Process Holdup). For many operations, the mass of the fissionable material removed from the workstation after an operation is less than that introduced before the

operation. This difference is assigned to "box loss." By definition, all box loss is considered to be dispersible fissionable material (see Appendix A for definition). The amount of box loss assigned to a workstation can be reduced by cleaning the workstation to remove or recover any measurable amount of fissionable material. The amount of fissionable material remaining after the workstation is cleaned is assumed to be negligible. The box loss for that workstation is then considered to be zero for criticality safety purposes, and the SNM material control and accountability mass inventory is adjusted.

CAUTION

Only Materials Management is authorized to "zero" a workstation's SNM material control and accountability mass inventory.

3.7 Criticality Safety Mass Limit Guidelines for Isotopic Mixtures

Fissionable materials are not normally isotopically pure because they contain varying amounts of other fissionable or fissile isotopes. The subsections below provide guidance for several fissionable material mixtures commonly used at LLNL.

Weapons Grade Plutonium. The mass limits for isotopically pure ^{239}Pu are applicable to the sum of the masses of ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{241}Am in an isotopic mixture of plutonium provided the isotopic concentration of ^{240}Pu exceeds that of ^{238}Pu, ^{241}Pu, and ^{241}Am combined, and all isotopes are considered to be ^{239}Pu in computing mass. Thus, the ^{239}Pu mass limit may be applied to elemental plutonium for typical weapons grade plutonium.

Plutonium-238. The mass limits for isotopically pure ^{238}Pu may be applied to an isotopic mixture of ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{241}Am provided the plutonium contains at least 67% ^{238}Pu, and the isotopic concentration of ^{241}Pu and ^{241}Am is less than that of ^{240}Pu.

Enriched Uranium. The mass limits for isotopically pure ^{235}U may be applied to isotopic mixtures of ^{234}U, ^{235}U, ^{236}U, and ^{238}U of any enrichment provided that ^{234}U is considered to be ^{235}U in computing the mass.

Uranium-233. The mass limits for isotopically pure ^{233}U may be applied to isotopic mixtures of ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U of any concentration provided that ^{234}U and ^{235}U are considered to be ^{233}U in computing the mass.

Natural Uranium and Depleted Uranium. Natural uranium consists of elemental uranium containing 0.711% by weight of the fissile isotope ^{235}U. Depleted uranium consists of elemental uranium containing less than 0.711% by weight of ^{235}U. Natural and depleted uranium may be authorized in unlimited amounts provided the uranium

is not intermixed or placed in close proximity to hydrogen, beryllium, deuterium, carbon, or their compounds. Activities with natural or depleted uranium exceeding 18,000 kg shall be reviewed for criticality safety by the ES&H Team.

3.8 Storage

Storage of fissionable material is subject to the same restrictions and requirements as any other activity involving fissionable material. Specific storage criteria for significant quantities of fissionable material for each facility shall be defined in a safety plan, which shall include the following criticality safety controls as appropriate:

Physical Controls

- Requirements specifying approved container types.
- Requirements for physical barriers to maintain a safe spacing between fissionable material containers.

Administrative Controls

- Fissionable material mass limits for each storage location, storage array, and/or room.
- Posting requirements.
- Requirements for the maintenance of inventory listings for fissionable material in each storage container, storage location, storage array, and/or room.

3.9 Shipping and Transfer

The Materials Management Section shall prepare fissionable materials for offsite shipment and transfer the material onsite between facilities. The Radioactive Hazardous Waste Management Division shall prepare waste containing fissionable materials for offsite shipment or onsite transfer between facilities. For further details, see Document 21.1, "Acquisition, Receipt, Transportation, and Tracking of Hazardous Material," in the *ES&H Manual,* the *Materials Control and Accountability Program Manual*, and Document 21.2, "Onsite Hazardous Materials Packaging and Transportation Safety Manual," in the *ES&H Manual*.

Offsite Shipment. Fissionable materials shall be packaged and transported in a manner that will prevent a criticality accident. The shipment shall be maintained in its original approved condition during transport, and any special restrictions shall be communicated to the driver or other responsible persons. Approved Department of Defense (DoD), Department of Energy (DOE), Department of Transportation (DOT), and Nuclear Regulatory Commission (NRC) packages shall be shipped in accordance

with federally approved standards (e.g., TP-20-7, Offsite Transportation Certificate, Code of Federal Regulations). Some shipments may require a criticality safety statement or a one-time shipping request, which will be provided by the Criticality Safety Section upon request.

Transport of NELAs. Nuclear Explosive-Like Assemblies (NELAs) containing "mock" high explosive and "live" fissionable materials shall be shipped in DoD shipping containers in accordance with TP-20-7 requirements or have the appropriate criticality safety statement for the corresponding warhead.

Onsite Shipments between Facilities. Fissionable materials to be transported onsite between facilities shall be either

- Packaged and transported in accordance with approved DoD, DOE, DOT, or NRC regulations for offsite shipments; or
- Packaged and transported in accordance with an approved safety plan or an approved onsite transportation safety manual.

Onsite Transfers within Facilities. Fissionable materials to be transferred within facilities shall be packaged and transported in accordance with an approved safety plan. The plan shall include

- Requirements specifying approved container types.
- Requirements for maintaining a safe spacing between fissionable material in transit and all other nearby fissionable material.
- The fissionable material mass limits for each transport movement.
- Limits for the maximum number of simultaneous transfers.
- Requirements for assuring that the transfer complies with all controls of the destination location.
- Posting requirements.
- Designation of responsible personnel.

3.10 Fissionable Material Inventory Records

Every facility or operation involving fissionable materials shall maintain an inventory record of all fissionable materials in the facility or operation. This inventory shall include all fissionable material in process operations, in storage (packaging), and sealed sources. As a practical matter, this requirement does not apply if the total inventory of fissionable material does not exceed 10% of the mass limit criteria in Section 3.5.

3.11 Audits and Inspections

Audits. At least once a year, every onsite facility with the potential for a criticality accident shall be formally audited. The audit shall be coordinated by the Criticality Safety Section leader of the Hazards Control Department. Criticality safety audits should be performed by recognized criticality safety experts who are independent of the activity. These audits are conducted to verify that applicable safety plans, standards, and DOE orders are being followed, and to confirm the adequacy of criticality safety controls. Any criticality safety deficiencies identified during an audit must be addressed by the responsible manager. Guidance for performing criticality safety audits may be found in *The Auditors Reference Manual*, *LLNL Criticality Safety Audits*.

A copy of the criticality safety audit report shall be sent to the appropriate line management through the associate director (AD) level, the deputy director for Operations, and the Assurance Review Office.

Inspections. Informal criticality safety inspections and walk-throughs may be performed by ES&H Team members and by Criticality Safety Section personnel at any time. Criticality safety deficiencies identified during such inspections will be brought to the immediate attention of the facility manager and the ES&H Team leader for resolution.

3.12 Training

Program and facility managers shall establish a program for selecting, training, and testing individuals and work supervisors who handle fissionable material. Training shall emphasize that workers must understand and follow the criticality safety control requirements. All workers in nuclear facilities with the credible potential for a criticality accident shall be retrained and retested annually on emergency response procedures, including an immediate evacuation exercise or drill. Biennial training/retraining in the fundamentals of criticality safety (or equivalent), which shall be tailored to the job responsibilities, is required for

- All personnel (and their work supervisors) who handle significant quantities of fissionable materials.
- All personnel (and their work supervisors) who work with or design equipment or devices that contain significant quantities of fissionable materials but do not require access to such materials.
- All personnel who are permitted to work unescorted in areas where significant quantities of fissionable materials are processed or stored, even though they are not required to handle such materials.

Supervisors may, at their discretion, require additional or more frequent training.

The Hazards Control Department offers formal training classes in the fundamentals of criticality safety in accordance with ANSI/ANS-8.20.

4.0 Noncompliance with Controls

4.1 Noncompliance with Criticality Safety Controls

A noncompliance with a criticality safety control is defined as any deviation from safety plans that may affect the criticality safety of any activity involving fissionable materials. This definition applies to noncompliance with criticality safety mass limits, moderator limits, or any other controlled parameters. Table 3 contains a list of actions to be taken if noncompliance with a criticality control is identified. A criticality safety noncompliance classified as severity index 1, 2, or 3 (as described in Table 4) is considered a criticality safety violation.

Table 3. Actions required for noncompliance with criticality safety controls.

Condition	Actions
A noncompliance with a criticality safety control or limit is found or suspected to have occurred.	• Suspend all affected activities immediately and, if it is safe to do so, place these activities in a safe static situation (i.e., where the form and geometry of the fissionable material remain unchanged). • Leave the immediate area and prevent others from entering within 15 ft of the fissionable material, if possible. • Report the suspected violation to the appropriate supervisor and facility manager.
The activity has been safely suspended and placed in a safe static situation.	• Prevent personnel from entering the area within 15 ft of the fissionable materials. • Notify the appropriate ES&H Team of the noncompliance. The ES&H Team shall notify the Criticality Safety Section. • Develop a recovery plan mutually acceptable to Criticality Safety Section, the ES&H Team, the Responsible Individual (RI), and the facility manager, and carry out the recovery in accordance with the plan.
The activity cannot be safely suspended (dynamic situation)	• Decide whether to stop the activity or evacuate the immediate area, or both. This decision is to be made by the supervisor (RI) or senior operator in consultation with facility management, the ES&H Team, and the Criticality Safety Section and shall be based foremost on consideration for their own safety and that of others, and whether the process will evolve into a more dangerous situation if permitted to proceed. • Determine any subsequent course of action in consultation with the ES&H Team and the Criticality Safety Section at the earliest opportunity. This is a function of the facility manager.

Table 4. Severity index and reporting levels for noncompliance with criticality safety controls.

Severity index	Minimum reporting level	Description of condition
1	Emergency	A criticality accident.
2	Unusual	Violation of the double-contingency criticality specifications, such that no valid controls are available to prevent a criticality accident.
3	Off-normal	Any nuclear criticality safety noncompliance that results in a loss of contingency, such that only one valid criticality control remains in place.
4	Internal	Of two contingencies, one is unaffected and the other is substantially intact. or Of several contingencies, failure has occurred among one or more, but at least two or more claimed contingencies remain unchallenged.

4.2 Reporting Noncompliances

Every noncompliance with criticality safety controls shall be reported to facility management, who then shall make notifications in accordance with the appropriate actions in Table 3. Additional reporting requirements are listed below:

- The Criticality Safety Section shall prepare and send to the facility manager a memorandum describing the noncompliance and recommending an assigned severity index (given in Table 4) and actions for correcting the problem.
- The facility manager shall report the noncompliance in accordance with the guidance in Table 4, the requirements in the LLNL implementing procedure for DOE O 232.1, "Occurrence Reporting and Processing of Operations Information," and the Price Anderson Amendments Act Noncompliance Reporting Guidelines. When reporting a noncompliance, the facility manager shall take into consideration aggravating and mitigating factors (e.g., recurrence and severity) as these may warrant a higher reporting level. Noncompliances classified as severity index 4 are not reportable to external organizations. However, the responsible line organization shall ensure that the noncompliance is adequately documented and any action items are tracked through closure.
- The facility manager shall provide a copy of all documentation associated with each noncompliance to the Criticality Safety Section.

5.0 Emergency Response

5.1 Criticality Accidents

Criticality accidents shall be investigated and reported in accordance with current LLNL policy. Refer to Document 4.5, "Incidents—Notification, Analysis, and Reporting," in the *ES&H Manual* for details.

The following subsections describe procedures and features designed to mitigate the consequences of a criticality accident.

Criticality Alarm System. Each facility or activity involving the use of fissionable materials in excess of 700 g of ^{235}U, 520 g of ^{233}U, or 450 g of ^{239}Pu shall be evaluated to determine if a criticality alarm system (CAS) is required. This system shall be capable of activating an Immediate Evacuation Alarm (IEA) that is audible throughout the facility (see Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the *ES&H Manual*, and ANSI/ANS-8.3). Each facility or activity that requires a CAS shall hold an evacuation exercise or drill at least once a year. This exercise shall be announced in advance.

If a required CAS is not fully operational, all work with fissionable materials in the affected areas shall be stopped and all fissionable material operations in progress shall be brought to a safe "standby" condition. The facility manager shall inform all facility personnel of the work stoppage and when work can be resumed.

Response to an Immediate Evacuation Alarm. If the IEA activates, all personnel shall immediately leave the building and report to the designated assembly area. The following shall be done at the assembly area:

- The facility manager (or designee) shall ensure (by "head count") that all personnel have left the facility.
- All individuals shall have their nuclear accident dosimeter surveyed to determine if they were exposed to high levels of neutron radiation. This survey shall be governed by the circumstances leading to the evacuation.
- Evacuated personnel shall remain in the assembly area until directed otherwise by facility management. The cause of the alarm shall be determined before normal operations can begin.
- Reentry to the facility shall not be authorized until it is verified that the likelihood of a recurrence (spontaneous or otherwise) of a critical condition is remote.

If a criticality accident has occurred, reentry into the facility shall be granted only by authorized personnel and governed by the authorized radiation dose limits that a

rescuer may receive during an emergency (see Document 22.6, "Exposure to Radiation in an Emergency," in the *ES&H Manual* for details).

Nuclear Accident Dosimeters. Nuclear Accident Dosimeters (NADs) are located in fixed locations throughout nuclear facilities with a potential for a criticality accident. Placement of NADs within a facility allows for assessment of the radiation dose and spectral characteristics resulting from a criticality accident. NADs are unobtrusive, require no routine maintenance, and may provide vital information in determining the levels and extent of medical treatment for injured personnel. NADs shall meet the requirements of ANSI/ANS-N13.3, "Dosimetry for Criticality Accidents." The specific locations of all NADs within a facility will be formally documented and the documentation maintained by the facility manager.

5.2 Fire-Fighting Guidelines

The possibility of a criticality accident may increase if water or other moderating materials are used to fight fires involving fissionable materials. Because of this concern, safety plans shall describe the fire hazards associated with the materials used in experiments or operations. Examples of fire hazards include

- Fire in an area where a container of fissionable materials has ruptured or opened.
- Fire in a glove box where fissionable materials are handled, processed, or stored.
- Fire involving pyrophoric fissionable materials (e.g., metal fines, chips, or hydrides).

Operations personnel shall consult with fire safety personnel to identify credible fire hazards involving fissionable materials for a planned activity. The approved safety plan for each operation shall include the criticality hazard type assigned to the operation by the Criticality Safety Section based on its evaluation, as well as any unique or unusual responses in the event of a fire.

The definitions for the criticality hazard types are

- **Criticality Hazard Type 1.** Water may be used as required. Total flooding will not cause a criticality incident. Handle as any radioactive material fire.
- **Criticality Hazard Type 2.** Water is allowed only if fissionable materials are not involved in the fire or they can be safely removed (or isolated) from the fire.
- **Criticality Hazard Type 3.** Water is not allowed.

Criticality Hazard Type 1 shall be assumed for any workstation or activity not assigned a Criticality Hazard Type by the authorized safety plan. The facility manager shall assure that fire safety personnel are informed of all workstations or activities assigned Criticality Hazard Types 2 and 3 so that appropriate information can be incorporated into emergency response procedures. All Criticality Hazard Types 2 and 3 shall be posted within the facility, as appropriate.

6.0 Responsibilities

All workers and organizations shall refer to Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management" in the *ES&H Manual* for a list of general responsibilities. This section describes specific responsibilities of LLNL organizations and workers who have key safety roles. The following sections describe roles and responsibilities for the Criticality Safety Program as an element of the Laboratory's integrated ES&H Program.

6.1 General

The primary line of responsibility for criticality safety with regard to fissionable material extends from the Laboratory Director through the program and facility ADs to authorized users who have hands-on responsibility for activities involving fissionable material. These responsibilities are detailed in Sections 6.2 and 6.3. Approval of a Facility Safety Plan (FSP), Operational Safety Plan (OSP), or other safety procedure by the program and facility ADs signifies that the proposed activity (or operation of the facility) complies with all applicable controls and requirements and that line management accepts the residual risk.

The Laboratory Director also assigns responsibility for the institutional aspects of criticality safety through the associate director for the Safety and Environmental Protection Directorate to the Hazards Control Department; these responsibilities are described in Section 6.4.

6.2 Program

Within a program, the line of responsibility extends from the program AD to the program leader, principal investigator, or Responsible Individual for that operation. The program AD (or designee) is responsible for ensuring that all ES&H requirements, including criticality safety requirements, are implemented in program activities. The program AD is also responsible for developing and implementing any OSP or other safety procedure covering a proposed operation with fissionable material. (The process

for developing safety plans is prescribed in Document 2.2 and Document 3.3, "Operational and Facility Safety Plans," in the *ES&H Manual*.)

6.3 Facility

Within the host facility where the activities are to be conducted, the line of responsibility extends from the facility AD to the facility manager, who is responsible to the facility AD for the facility's infrastructure and facility safety analyses, unreviewed safety question determination, and facility-specific training. The facility AD (or designee) is also responsible for developing and approving the FSP for his/her facility. The FSP, Document 2.2, "in the *ES&H Manual,* and Section 3 define the circumstances under which a proposed operation requires an OSP. The facility AD (or designee) shall concur that the operations described in the OSP are consistent with the facility's Technical Safety Requirements (TSRs) or Operational Safety Requirements (OSRs), as appropriate, and the facility safety authorization basis, that is, both the hazard analysis and accident scenarios and their associated assumptions.

6.4 Hazards Control Department

- Provides criticality safety support to programs and facilities.
- Maintains the Criticality Safety Section, which has knowledgeable safety professionals competent in the field of criticality safety. The Criticality Safety Section leader reports to the Safety Programs Division leader who reports to the department head. As part of the Laboratory's integrated ES&H Program, criticality safety engineers are assigned by the Criticality Safety Section leader to provide technical support to LLNL programs. This technical support is coordinated through the ES&H Team and the ES&H Team leader.

Criticality Safety Section Leader

- Ensures the activities specified as the responsibility of criticality safety engineers are conducted.
- Establishes procedures to ensure the technical adequacy of the evaluation and any guidance given.
- Maintains a staff of qualified criticality safety experts to provide criticality safety support to all LLNL programs and activities.
- Ensures that evaluations and guidance are consistent with regulations, standards, and policies.
- Establishes a training program to maintain a qualified staff of criticality safety experts.

- Coordinates the annual criticality safety audit of LLNL-designated nuclear facilities.
- Promotes professional development for criticality safety engineers.
- Ensures the adequacy and validity of computer codes or other information used to perform the evaluation.

Criticality Safety Engineers

- Provides guidance in all aspects of criticality safety.
- Assists facility and programmatic management in the analysis, development, and implementation of criticality safety controls for safety plans.
- Participates in the preparation and presentation of criticality safety training for facility and program personnel, including fundamental training on criticality principles and training specific to operations.
- Informs facility and programmatic management of changes to this document in the *ES&H Manual.*
- Provides technical support to facility and programmatic management during abnormal operations, including emergency response and recovery support capability for incidents involving criticality safety issues.
- Assists facility staff in preparing criticality safety sections for safety plans.
- Reviews safety plans for activities involving fissionable materials.
- Prepares criticality safety statements about LLNL's weapons, weapon components, or other items containing fissionable materials.
- Provides criticality safety support, including appropriate calculations and use of consensus standards or handbook guidance.
- Provides training on the fundamentals of criticality safety.
- Supports periodic audits and inspections of activities involving fissionable materials and maintains a record of each audit or inspection.
- Evaluates and reviews the design and installation of criticality alarm systems.

ES&H Team Leader

- Assures that the criticality safety engineers provide appropriate criticality safety support to LLNL programs.
- Coordinates the review of safety plans and operations with the Criticality Safety Section.

- Coordinates additional criticality safety activities in support of programs and facilities.

6.5 Materials Management Section

- Transfers fissionable materials, other than waste, between onsite facilities.
- Prepares fissionable materials for offsite shipment in accordance with established procedures.
- Receives fissionable materials from offsite shippers in accordance with established procedures.

6.6 Radioactive and Hazardous Waste Management Division

- Transfers waste containing fissionable material between onsite facilities.
- Prepares radioactive waste containing fissionable material for offsite shipment to treatment or disposal facilities.

6.7 Assurance Review Office

- Provides an independent, internal ES&H assessment program to assure that Laboratory ES&H policies and their implementation are consistent with Laboratory requirements, DOE orders, and ES&H regulations.
- Conducts a review to assess the staffing, management, and appropriate funding of the Criticality Safety Program.
- Performs an assessment of the LLNL Criticality Safety Program at least every three years.

7.0 Work Standards

7.1 Work Smart Standards

DOE O 232.1A, "Occurrence Reporting and Processing of Operations Information."

DOE O 420.1, Change 3, "Facility Safety", Attachment 2, Contractor Requirements Document, Paragraph 4 except 4.1.2, 4.1.3, and excluding the invocation of ANS 8.9, ANS 8.10, and ANS 8.17 and other references to explosives safety.

DOE O 5610.12, "Packaging and Offsite Transportation of Nuclear Components and Special Assemblies Associated with the Nuclear Explosives."

ANSI/ANS-8.20-1991, "Nuclear Criticality Safety Training."

ANSI/ANS-8.22-1997, "Nuclear Criticality Safety Based on Limiting and Controlling Moderators."

ANSI/ANS-8.23-1997, "Nuclear Criticality Accident Emergency Planning and Response."

ANSI N13.3-1969, "Dosimetry for Criticality Accidents."

7.2 Other Requirements

ANSI/ANS-8.1-1983, R88, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors."

ANSI/ANS-8.3-1986, "Criticality Alarm System."

ANSI/ANS-8.5-1986, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."

ANSI/ANS-8.6-1983, R88, "Safety in Conducting Subcritical Neutron-Multiplication Measurements In Situ."

ANSI/ANS-8.7-1975, R87, "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials."

ANSI/ANS-8.12-1987, R93, "Nuclear Criticality Control and Safety of Homogeneous Plutonium-Uranium Fuel Mixtures Outside Reactors."

ANSI/ANS-8.15-1981, R87, "Nuclear Criticality Control of Special Actinide Elements."

ANSI/ANS-8.19-1984, R89, "Administrative Practices for Nuclear Criticality Safety."

ANSI/ANS-8.21-1995, "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors."

8.0 Resources for More Information

8.1 Contacts

For additional information about criticality safety issues, contact the appropriate ES&H Team or the Criticality Safety Section.

8.2 Other Resources

DOE-STD-3007-93, "Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities."

Harper, W. R., *The Auditors Reference Manual, LLNL Criticality Safety Audits* (August 1996).

Criticality Safety Section Quality Assurance Implementation Plan and Procedures.

Appendix A

Terms and Definitions

Authorized user	An individual within the Laboratory who is authorized to work with fissionable material in accordance with an approved safety plan.
Critical mass	The minimum mass of fissionable material that can sustain a fission chain reaction with a specified geometrical arrangement and material composition.
Criticality accident	The release of energy as a result of accidentally producing a self-sustaining or divergent fission chain reaction.
Criticality safety statement	A statement that lists the criteria governing criticality safety.
Depleted uranium	Depleted uranium consists of elemental uranium containing less than 0.711% by weight of the fissile isotope ^{235}U. Depleted uranium is often represented by the symbol D-38 or D38.
Dispersible fissionable material	(1) Any solid piece containing fissionable material with a total mass ≤10g. (2) Liquids, gases, solutions, slurries, powders, chips, lathe turnings, filings, hydrides, or oxides containing fissionable materials. (3) Any fissionable material carried as "box loss." (4) Other fissionable materials so defined in a safety plan.
Double-contingency principle	A nuclear criticality safety principle stating that process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

Dynamic situation	A situation in which changes are occurring to the form and geometry of the fissionable material or its nearby surroundings. This includes moving the fissionable material within the work area. Any changes to the nearby surroundings that could affect the moderation, reflection, absorption, shielding, or escape of neutrons from the fissionable system are also included under this definition.
Enriched uranium	Enriched uranium consists of elemental uranium containing more than 0.711% by weight of the fissile isotope ^{235}U. Enriched uranium is often identified as low enriched uranium (LEU), intermediate enriched uranium (IEU), highly enriched uranium (HEU), or oralloy (Oy).
Fissile materials	Fissionable isotopes capable of sustaining a neutron chain reaction induced by neutrons of any energy (including thermal or low-energy neutrons). Fissile isotopes include ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu.
Fissionable materials	Isotopes capable of fission induced by neutrons of some energy. Fissionable isotopes include ^{237}Np and ^{238}Pu.
Natural uranium	Natural uranium consists of elemental uranium containing 0.711% by weight of the fissile isotope ^{235}U. Natural uranium is also known as tube alloy and may be represented by the symbol Tu.
Safety plan	A formal (i.e., written, reviewed, and approved) document describing procedures, controls, and limits for operations involving fissionable materials and other hazardous operations.
Significant quantity of fissionable material	Any quantity of fissionable material that does not satisfy the criteria in Section 3.5.
Static situation	A situation in which no changes are occurring to the form and geometry of the fissionable material or its nearby surroundings.

Work supervisor	The person designated by management to be the day-to-day supervisor of an authorized employee. For an authorized employee assigned a specific, short-term assignment in an area, this may be the discipline supervisor. Authorized employees assigned duties in more than one area may have more than one work supervisor. The work supervisor shall ensure that the authorized employee is trained and qualified to perform assigned tasks.
Workstation	For the purposes of criticality safety, an enclosure, assembly table, or specific item of equipment with spatial boundaries that are well defined by physical barriers or administratively specified barriers.